REMOTE SENSING BY UNIVERSITY OF TOKYO'S PICO-SATELLITE PROJECT "PRISM"

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ABSTRACT

This paper presents our design concept and some technological topics in our ongoing project, "PRISM" which stands for "Pico-satellite for Remote-sensing and Innovative Space Missions". Nakasuka laboratory in University of Tokyo has been designing and developing this pico-satellite since 2002. Its main mission is remote sensing. Basically, we aim to obtain Earth images with as high resolution as about 30 meters by its compact spacecraft bus, which is a 17cm*17cm*25cm and will be weigh less than 5kg. PRISM has a refracting optical system using one group of lenses, unlike most of the Earth Observation satellites. A main reason why we adopted this kind of optics is the possibility of downsizing the whole optics with extensible tube framework for telescope. Moreover, we've been dedicated to design and development of many components in every subsystem. The fundamentals of its bus technologies are on the basis of the experience in our previous project, "CubeSat XI" [sai] [1], which was launched in 2003 and has been operative for more than 16 months. We are now developing PRISM engineering model with a hope to launch its flight model between 2005 and 2006.

1. INTRODUCTION

1.1. Previous Project -CubeSat XI

Nakasuka laboratory built its first pico-satellite CubeSat XI-IV [sai-four] by 2002, which was launched by the Russian rocket "Rockot" together with other seven micro- and pico-satellites on June 30, 2003. XI-IV, which is shown in Figure 1, has verified pico-satellite bus technologies and commercial-off-the-shelf components including SEL-protection circuit, low power consumption micro-controller, compact HAM transceiver unit, Li-ion secondary battery, passive attitude control using permanent magnet, and a CMOS camera. Figure 2 shows images taken by the camera on XI-IV.

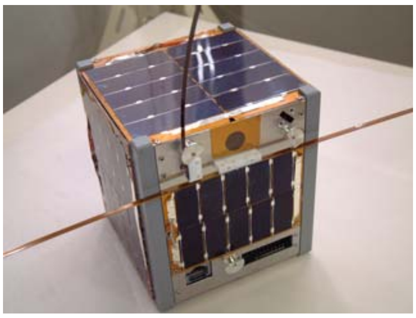

Fig.1: Outlook of XI-IV

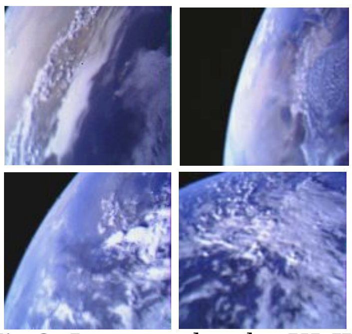

Fig.2: Images taken by XI-IV

1.2. Motivation for PRISM

Growing interest in the global environment requires more opportunities of Earth observation through satellites with lower cost. Universities such as Surrey in the UK and the Berlin Institute of Technology have already successfully built very small satellites, which weigh 50-100kg, with a remote-sensing mission, but they are still larger than those that we can design and develop at a laboratory in a university. PRISM aims to acquire Earth images with about 30 meters of ground resolution by a very compact spacecraft bus with a mass of 3-5kg. It should be highly innovative if we could realize this level of resolution with such a tiny satellite.

2. MISSION OF PRISM

2.1. Mission Concept

Both of the long focal length and the large aperture are necessary to acquire high-resolution images. Figure 3 illustrates the outlook of PRISM. We adopted a refracting optical system with a group of lenses, although many conventional micro-satellites select reflective optics using several mirrors or refracting optics with a few groups of lenses. We selected this type of optics mainly because the optics with only one group of lenses has much better tolerance of its optical axis offset than the others and because we want to test how much resolution can be obtained by a simple refraction optics. Therefore, we can design the tube framework of PRISM's telescope with a totally different concept. That is, PRISM deploys an extensible boom after its separation from the launching rocket. The boom has a unit of lenses on its end, and it works as a structure of telescope as well as a gravity gradient boom. This boom is designed to be 80 cm long after extension and about 10 cm long before extension.

PRISM also has solar array paddles as another deployment structure. Solar arrays are to be attached on both sides of a paddle for more power generation. These deployable mechanisms are fairly preferable to all kinds of satellites since they can be space-saving and endure launcher's vibration easily during launch. Figure 4 depicts these mechanisms, and Figure 5 shows a pre-engineering model of its extensible boom.

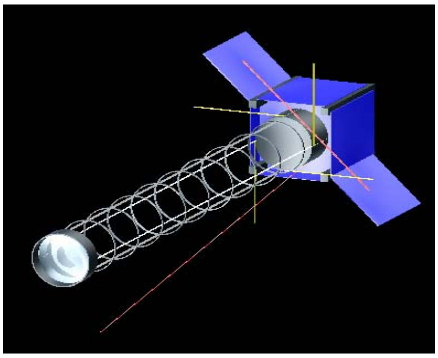

Fig.3: Outlook of PRISM

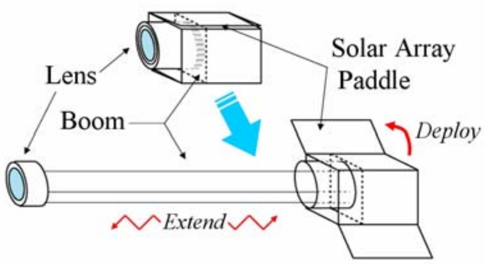

Fig.4: Extensible Boom and Deployable Solar Array Paddles

2.2. System Design

PRISM consists of the following six subsystems, besides the ground station. That is, Optics, ADCS (Attitude Determination and Control System), C&DH (Command and Data Handling), Communication, Power, and Structure & Thermal Design.

Currently, around 20 graduate and undergraduate students engaged in this project. Most students take charge of two subsystems, which helps us learn wide range of knowledge from the aspect of an educational program, and is also beneficial to smooth interface of the project. Receiving feedback from XI-IV, the system design of PRISM has been refined in many points. Figure 6 briefly shows the data flow of its engineering model.

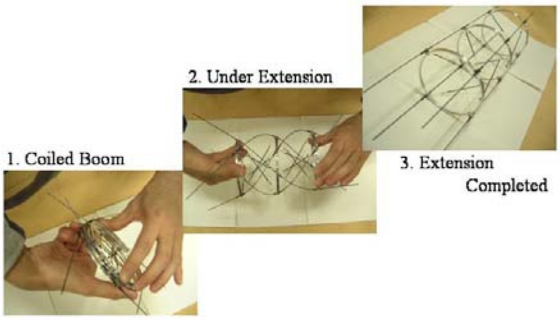

Fig.5: Extensible boom

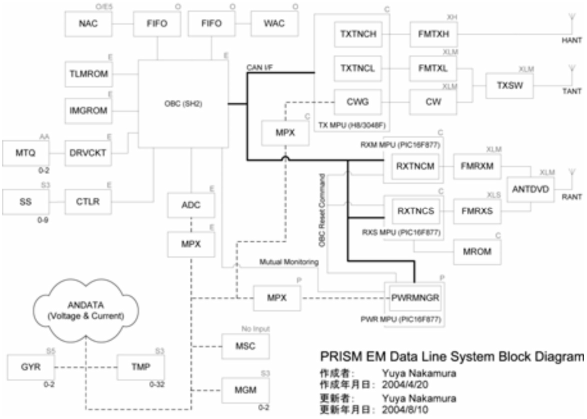

Fig.6: PRISM System Block Diagram.

2.3. Outline Specification

We briefly present the outline specification of PRISM by Table 1. Details are available in PRISM web site [2], and some reports, in which the paper of [3] is the latest one.

Table 1: Outline Specification of PRISM

- **Optics**
  - NAC (Narrow Angle Camera) : Apochromatic lens, extensible boom, baffles, and Color CMOS image sensor with 1.3 mega-pixels
    Ground Resolution: 10m (Best Effort) - 50m, Image area: 7-8km
  - WAC (Wide Angle Camera) : Color CMOS camera module
    Ground Resolution: 6km, Image area: 600km
- **ADCS**
  - Actuators : MTQ (3 axes : in-house product), Reaction Wheels (1 axis)
  - Sensors : Magnetometers (3 axes), Gyros (3 axes), Sun Sensors (10pcs)
- **C&DH**
  - High-performance CPU(SH2) with RTOS
  - CAN (Control Area Networks) for reduction of wired connections
- **Communication**
  - FM Downlink system with high data rate (GMSK: 9600bps, 3W)
  - Another FM Downlink (FSK: 1200bps, 800mW): Space qualified by XI-IV.
  - FM Uplink (FSK: 1200bps): Space qualified by XI-IV.
  - Beacon (CW: 50wpm, 100mW): Space qualified by XI-IV.
- **Power**
  - GaAs type solar cells (efficiency: about 20%)
  - Li-ion polymer type in 2 series
  - Intelligent power management system using PPT (Peak Power Tracking)
- **Structure & Thermal Design**
  - Smart mechanism (Extensible boom, Deployable Solar Array Paddles)

2.4. Success Levels

To clarify the objective of our project and mission goal, we have set the success levels of PRISM project according to the difficulty level of each objective.

■ Minimum Success

– After release from the launcher, to determine the orbit of PRISM and to establish communication with our ground station

– To obtain any telemetry and images from WAC

The followings are higher achievements than what XI-IV has achieved.

■ Middle Success

– To deploy the solar array paddles and the extensible boom, and to confirm their secure deployment

■ Full Success

– To have the attitude control system work correctly, and to succeed all missions to be minimally verified

– To obtain images with desired resolution

■ Advanced Success

– To specify the location of the NAC image on the Earth using the WAC image

– To verify various kinds of control algorithms by reprogramming OBC

3. CONCLUSIONS

PRISM is the second small satellite project for our laboratory with a high-resolution remote-sensing mission. Moreover, it has many other missions as a pico-satellite, such as the deployment of an extensible boom and solar array paddles, active attitude control system, high data rate communication as well as the reinforced bus technology verification. We believe that PRISM will be a pathfinder for a new type of Earth observation satellites.

We are now in the EM design phase, and the completion of the flight model is scheduled for the next spring with the hope of the launch between 2005 and 2006.

ACKNOWLEDGEMENT

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REFERENCES

[1] CubeSat XI Web Site: http://www.space.t.u-tokyo.ac.jp/cubesat/index-e.html

[2] PRISM Web Site: http://www.space.t.u-tokyo.ac.jp/prism/

[3] Yuya Nakamura, Takashi Eishima, Masaki Nagai, Ryu Funase, Akito Enokuchi, Kenji Nakada, Yuliang Cheng, Ernesto Toshiyuki Takei, Tsukasa Funane, Fumiki Sasaki, Yuta Nojiri, Takaya Yamamoto, Eri Nagayama and Shinichi Nakasuka "University of Tokyo's Ongoing Student-Lead Pico-Satellite Projects -CubeSat XI and PRISM-", IAC-04-IAA-4.11.4.06, 55th International Astronautical Congress, Vancouver, Canada, October 2004

[4] UNISEC Web Site: http://www.unisec.jp/